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EXHAUST EMISSION CONTROL DEVICE FOR INTERNAL COMBUSTION ENGINE
[Nainen kikan no haiki joka sochi]

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[Claim(s)] /2*

[Claim 1] An exhaust emission control device of an internal combustion engine characteristically comprising a pre-catalyst containing an oxidation catalyst supported on a supporting layer made from titania or silica and disposed in the exhaust passage of the internal combustion engine and a particulate filter disposed in the exhaust passage downstream from the pre-catalyst and supporting a NO_x occlusion agent.

[Claim 2] The exhaust emission control device of an internal combustion engine according to Claim 1, characterized in that the exhaust emission control device is further equipped with a reducing agent supply means for supplying a reducing agent into the exhaust passage upstream from the pre-catalyst.

[Claim 3] The exhaust emission control device of an internal combustion engine according to Claim 2, characterized in that the reducing agent supply means supplies a reducing agent in such a manner so as to suppress the increasing temperature of the pre-catalyst when the particulate filter is recovered from poisoning.

[Detailed Explanation of the Invention]

[0001]

[Field of the Invention] The present invention relates to the technique of cleaning the exhaust of an internal combustion engine

* Claim and paragraph numbers correspond to those in the foreign text.

and particularly to the structure of a catalyst disposed in the exhaust system of an internal combustion engine.

[0002]

[Description of the Prior Art] In recent years, a demand has grown for improvement over the exhaust emission of an internal combustion engine installed in vehicles, etc. Particularly, diesel engines that consume light oil as fuel require a technology for cleaning fine particles (PM: Particulate Matter) such as soot and SOF (Soluble Organic Fraction) in addition to nitrogen oxide (NO_x) included in the exhaust.

[0003] Conventionally, in order to meet such demands, as in the case of the exhaust emission control device for an internal combustion engine described in Japanese Laid Open Pat. No. JP-A (Tokukai) H6-159037, for example, there is proposed a technique of disposing a particulate filter in the exhaust passage of an internal combustion engine, wherein the filter supports a NO_x occlusion agent which occludes nitrogen oxide (NO_x) in the exhaust air during high oxygen concentration but reduces/cleans and discharges the occluded nitrogen oxide (NO_x) under decreasing oxygen concentration of the exhaust air and the presence of a reducing agent.

[0004]

[Problem to be Solved by the Invention] According to the above-mentioned conventional exhaust emission control device of an internal combustion engine, when the SOF in the exhaust air is trapped on the

upstream end-face of the particulate filter, soot and the like in the exhaust air is absorbed and accumulated on the above-mentioned upstream end face via SOF, easily causing plugging in the upstream end-face of the particulate filter.

[0005] On the other hand, a possible method for suppressing the plugging in the upstream end-face of the particulate filter is that a catalyst capable of cleaning SOF (hereafter, called “pre-catalyst”) is disposed in the exhaust passage upstream from the particulate filter supporting the NO_x occlusion agent.

[0006] With the above-mentioned method, however, the pre-catalyst is sometimes subjected to sulfur oxide (SO_x) poisoning, and if the depoisoning process is carried out to the pre-catalyst in that situation, the particulate filter could be carelessly poisoned by the sulfur oxide (SO_x) discharged from the pre-catalyst.

[0007] This invention was developed in view of the above-mentioned various conditions and thereby has an object of providing a technology for preventing the deterioration of cleaning performance of a particulate filter in an exhaust emission control device for an internal combustion engine equipped with a particulate filter that supports a NO_x occlusion agent.

[0008]

[Means for Solving the Problem] The present invention uses the following means for solving the above-mentioned problems. Namely, the exhaust emission control device of an internal combustion engine

characteristically comprises a pre-catalyst containing an oxidation catalyst supported on a supporting layer made from titania or silica and disposed in the exhaust passage of the internal combustion engine and a particulate filter disposed in the exhaust passage downstream from the pre-catalyst and supporting a NO_x occlusion agent.

[0009] The greatest characteristic of this invention is that a pre-catalyst having an oxidation function is disposed upstream from the particulate filter supporting the NO_x occlusion agent and also the supporting layer of the pre-catalyst comprises titania (TiO_2) or silica (SiO_2) not easily occluding sulfur oxide (So_x).

[0010] Since this exhaust cleaning device of an internal combustion engine allows a pre-catalyst to oxidize and clean the SOF included in the exhaust, SOF does not attach to the upstream-side end face of the particulate filter. Subsequently, fine particles (PM: Particulate Matter) such as soot included in the exhaust air are not accumulated on the upstream-side end face of the particulate filter.

[0011] Further, since the support layer of a pre-catalyst comprises titania (TiO_2) or silica (SiO_2) not easily occluding sulfur oxide (SO_x), the pre-catalyst is never poisoned (SO_x poisoning) by the sulfur oxide (SO_x) in the exhaust air. Subsequently, as the pre-catalyst depoisoning process is no longer necessary, SO_x poisoning of particulate-filter attributed to pre-catalyst depoisoning process is prevented.

[0012] The exhaust cleaning device of the internal combustion engine concerning this invention may be further equipped with a reducing agent supply means for supplying a reducing agent disposed in the exhaust passage upstream from the pre-catalyst.

[0013] In this case, the reducing agent supply device supplies a reducing agent into the exhaust passage upstream from the pre-catalyst, for example, at the time of recovering the particulate filter from poisoning. Examples of poisoning of the particulate filter described here are poisoning by sulfur oxide (SO_x), poisoning by fine particles (PM: Particulate Matter) and the like.

[0014] The reducing agent supplied into the exhaust passage from the reducing agent supplying means flows into the pre-catalyst with exhaust air flowing from the upstream of the exhaust passage and then continuously flows into the particulate filter.

[0015] Once the reducing agent flows into the pre-catalyst, the heat of the pre-catalyst is taken by the reducing agent to prevent the temperature rising of the pre-catalyst. In this case, when exposed to high temperature, titania (TiO_2) and silica (SiO_2) composing the support layer of the pre-catalyst cause grain growth to possibly set off sintering of oxidized catalyst. However, when temperature increase is prevented by the supply of reducing agent described above, sintering of the oxidized catalyst is also prevented correspondingly.

[0016] Also, since a part of reducing agent flowing into the pre-catalyst reacts inside of this pre-catalyst and is evaporated and heat-decomposed, homogeneous mixing of the reducing agent and exhaust air becomes easier. As a result, the exhaust air flowing out from the pre-catalyst, in other words the gas flowing into the particulate filter, becomes gas of homogeneously mixed reducing agent and exhaust air, thereby allowing the reducing agent to be uniformly spread in a large area of the particulate filter, subsequently allowing the reproduction of particulate capturing capability or SO_x depoisoning to be performed suitably.

[0017]

[Embodiment of the Invention] Hereafter, concrete embodiments of the exhaust emission control device of an internal combustion engine concerning this invention is described based on the figures.

[0018] FIG. 1 is a diagram showing the outline configuration of an internal combustion engine and the suction-exhaust system thereof to which this invention is applied. The internal combustion engine 1 shown in FIG. 1 is a water-cooling 4-stroke cycle diesel engine which uses gas oil as fuel.

[0019] The internal combustion engine 1 is equipped with four cylinders, from No. 1 (#1) cylinder 2 to No. 4 (#4) cylinder 2. A fuel injection valve 3 which injects fuel directly into the combustion chamber of each cylinder 2 is disposed to the above-mentioned each of four cylinders 2 in the combustion chamber. Each

fuel injection valve 3 is connected with a pressure-accumulation chamber (common rail) 4 which accumulates fuel to predetermined pressure. A common-rail pressure sensor 4a is attached to the common rail 4 for outputting an electrical signal corresponding to the pressure of the fuel in the common rail 4.

[0020] Said common rail 4 is communicated to a fuel pump 6 via a fuel supply pipe 5. The fuel pump 6 operates as the drive source for driving the rotary torque of the output shaft (crank shaft) of the internal combustion engine 1 and is connected to a pump pulley 6a attached to the input shaft of this fuel pump 6 via a crank pulley 1a and a belt 7.

[0021] In the fuel injection system configured in this manner, when the rotary torque of the crank shaft is transmitted to the input shaft of the fuel pump 6, the fuel pump 6 is operated using the torque transmitted from the crank shaft to the input shaft of the fuel pump 6 as the drive source and discharges fuel supplied from the fuel tank (not shown in the figure) at prescribed pressure.

[0022] The fuel discharged from the above-mentioned fuel pump 6 is supplied to the common rail 4 via the fuel feeding pipe 5, then accumulated to a prescribed pressure by the common rail 4 and distributed to the fuel injection valve 3 of each cylinder 2. When a drive current is impressed on the fuel injection valve 3, the fuel injection valve 3 opens. As a result, fuel is injected from the fuel injection valve 3 into the fuel chamber of each cylinder 2.

[0023] Next, a branching inlet pipe 8 is connected to the internal combustion engine 1 wherein each branched pipe of the branching inlet pipe 8 is communicated to the combustion chamber of each cylinder 2 via an inlet port.

[0024] the branching inlet pipe 8 is connected to the intake air pipe 9, and this intake air pipe 9 is connected to an air cleaner box 10. The intake air pipe 9 disposed downstream from the air cleaner box 10 is attached with an airflow meter 11 which outputs an electrical signal corresponding to the intake air mass flowing through the inside of the intake air pipe 9 and an intake air temperature sensor 12 which outputs an electric signal corresponding to the temperature of the intake air flowing through the intake air pipe 9.

[0025] An intake air throttle valve 13 which adjusts the flow of the intake air flowing through the inside of the intake air pipe 9 is disposed at the site right above the branching intake air pipe 8 of the intake air pipe 9. An actuator 14 for throttling the intake air, which comprises a stepper motor or the like and opens and closes the intake air throttle valve 13, is mounted on the intake air throttle valve 13.

[0026] A compressor housing 15a of a centrifugal supercharger (turbocharger) 15 which operates using the heat energy of the exhaust air as the drive source is disposed to the intake air pipe 9 positioned between the airflow meter 11 and intake air throttle valve

13, while an intercooler 16 for cooling the intake air which has been compressed in the compressor housing 15a and has high temperature is disposed to the intake air pipe 9 positioned downstream from the compressor housing 15a.

[0027] In the suction system configured in this manner, dirt, dust, etc. in the intake air flowing into an air cleaner box 10 are removed by an air filter (not shown in the figure) in the air cleaner box 10 and then flows into the compressor housing 15a via the intake air pipe 9.

[0028] The intake air flowing into the compressor housing 15a is compressed by the rotation of internal compressor wheel of the compressor housing 15a. After the intake air having been compressed in the compressor housing 15a to have high temperature is cooled by the intercooler 16, the flow quantity thereof is adjusted by the intake air throttle valve 13 if needed and flows into the branching intake air pipe 8. The intake air flowing into the branching intake air pipe 8 is distributed into the combustion chamber of each cylinder 2 via each branched pipe and is burned using the fuel injected from the fuel injection valve 3 of each cylinder 2 as the ignition source.

[0029] On the other hand, the branching exhaust pipe 18 is connected to the internal combustion engine 1, wherein each branched pipe of the branching exhaust pipe 18 is communicated to the

combustion chamber of each cylinder 2 via an exhaust port (not shown in the figure).

[0030] The branching exhaust pipe 18 is connected with the turbine housing 15b of the centrifugal supercharger 15. The turbine housing 15b is connected with the exhaust pipe 19, and this exhaust pipe 19 and a muffler (not shown in the figure) are connected downstream.

[0031] An exhaust emission control device 20 is disposed in the middle of said exhaust pipe 19 for cleaning the harmful gas component in the exhaust air, and a pre-catalyst 21 is disposed to the exhaust pipe 19 upstream from this exhaust emission control device 20.

[0032] The exhaust emission control device 20 comprises a particulate filter for trapping fine particles (PM: Particulate Matter) such as soot and SOF (Soluble Organic Fraction) included in the exhaust air and a casing for storing the particulate filter. Note that hereafter the exhaust emission control device 20 is referred to as particulate filter 20.

[0033] The above-mentioned particulate filter 20 is a wall-flow type filter consisting of a porous substrate which is arranged in such, for example, that a first exhaust flow passage having an open base end and a closed terminal end and a second exhaust flow path having a closed base end and an open terminal end are alternately arranged to form a honeycomb-like shape with a partition wall positioned therebetween.

[0034] As the above-mentioned porous substrate, cordierite, etc. are mentioned. A carrier layer consisting of a coat material, such as alumina (Al_2O_3) or zirconia (ZrO_2), is formed on the surface of the partition wall of this substrate and inner wall faces of the thin holes in the partition wall, and the NO_x occlusion agent and oxidation catalyst are supported by the carrier layer.

[0035] As the above-mentioned NO_x occlusion agent, an example can be at least one material selected from a group consisting of alkaline metals, such as potassium (K), sodium (Na), lithium (Li), or cesium (Cs), alkaline-earth metals, such as barium (Ba) or calcium (Ca), alkaline-earth metals, such as strontium (Sr), rare earth materials, such as lanthanum (La) and yttrium (Y). As the above-mentioned oxidation catalyst, precious metals, such as platinum (Pt), can be exemplified.

[0036] The particulate filter 20 constituted in this manner cleans the exhaust air according to the following mechanism.

[0037] First, when the oxygen concentration of the exhaust air flowing into the particulate filter 20 is high, nitrogen oxide (NO_x) included in the exhaust air is occluded, absorbed, or taken up by the NO_x occlusion agent (hereafter, the process is simply referred to "occlusion").

[0038] Then, when the oxygen density of the exhaust air flowing into the particulate filter 20 decreases, the NO_x occlusion agent emits nitrogen oxide (NO_x) being occluded therein. At that time, if

reducing components, such as hydrocarbon (HC) and carbon monoxide (CO), exist in the exhaust, the oxidation catalyst promotes the oxidation-reduction reaction between reducing components and nitrogen oxide (NO_x), subsequently allowing hydrocarbon (HC) and carbon monoxide (CO) to be oxidized to form water (H_2O) or carbon dioxide (CO_2) while nitrogen oxide (NO_x) is reduced to nitrogen (N_2).

[0039] Since the NO_x occlusion capacity of the NO_x occlusion agent has a limitation, the NO_x occlusion capacity of the NO_x occlusion agent must be recovered before the saturation of the NO_x occlusion capacity of the NO_x occlusion agent. As a method of recovering the NO_x occlusion capacity of the NO_x occlusion agent, for example, fuel [hydrocarbon (HC)] is added to the exhaust air from the fuel addition valve 25 so as to lower the oxygen concentration in the exhaust air flowing into the particulate filter 20 while the amount of reducing components is increased at the same time, thereby recovering the NO_x occlusion capacity of the NO_x occlusion agent.

[0040] On the other hand, the particulate filter 20 itself traps PM included in the exhaust air when the exhaust air in the first exhaust passage flows into the second exhaust passage through fine holes in the partition wall. However, since the PM amount that can be trapped by the particulate filter 20 itself is limited, PM trapped by the particulate filter 20 must be cleaned arbitrarily.

[0041] In this case, the NO_x occlusion agent and oxidation catalyst which are supported by the particulate filter 20 occlude and

reduce the nitrogen oxide (NO_x) in the exhaust air as described above, and when the NO_x occlusion agent is heated by the reaction heat generated by the reducing nitrogen oxide (NO_x), active oxygen is generated by the NO_x occlusion agent.

[0042] The active oxygen generated in this manner is highly reactive and quickly reacts with the PM being trapped in the particulate filter 20, thus oxidizing and purifying the PM.

[0043] The pre-catalyst 21 comprises an oxidation catalyst for oxidizing SOF (Soluble Organic Fraction), unburned components, etc. included in the exhaust air and a casing for housing this oxidation catalyst. The concrete composition of this pre-catalyst 21 will be described later.

[0044] In the exhaust system constituted in this manner, the gaseous mixture (burned gas) which is burned in each cylinder 2 of the internal combustion engine 1 is discharged to the branching exhaust pipe 18 via the exhaust port and subsequently flows into the turbine housing 15b of the centrifugal supercharger 15 from the branching exhaust pipe 18. The exhaust air flowing into the turbine housing 15b rotates the turbine wheel supported rotatably in the turbine housing 15b. At that time, the rotary torque of the turbine wheel is transmitted to the compressor wheel of the above-mentioned compressor housing 15a.

[0045] The exhaust air discharged from said turbine housing 15b flows into the pre-catalyst 21 via the exhaust pipe 19 to oxidize and

purify the SOF, unburned fuel components, etc. The exhaust air having purified SOF, unburned fuel components, etc. by the pre-catalyst 21 flows into the particulate filter 20 where soot, nitrogen oxide (NO_x), etc. contained in the exhaust air are removed or cleaned. The exhaust air having soot and nitrogen oxide (NO_x) removed or cleaned with the exhaust emission control device 20 flows through the exhaust pipe 19 and is released into the atmosphere.

[0046] Next, the branching exhaust pipe 18 and the branching inlet pipe 8 of the internal combustion engine 1 are made to communicate with each other via an exhaust-gas recirculation passage (EGR passage) 22 which makes a part of exhaust air flowing through the branching exhaust pipe 18 recirculate into the branching inlet pipe 8.

[0047] A flow quantity adjustment valve (hereafter, referred as EGR valve) 23 comprising an electromagnetic valve, etc. for changing the flow quantity of the exhaust air (hereafter called EGR gas) flowing in the EGR passage 22 corresponding to the volume of the impressed electric power is disposed in the middle of said EGR passage 22.

[0048] An EGR cooler 24 which cools the EGR gas flowing through this EGR passage 22 is disposed upstream from the EGR valve 23 in the above-mentioned EGR passage 22.

[0049] In the exhaust-gas recirculation mechanism constituted in this manner, when the EGR valve 23 opens so as to open the EGR

passage 22, a part of the exhaust air flowing into the branching exhaust pipe 18 flows into the EGR passage 22 and is guided to the branching inlet pipe 8 through the EGR cooler 24.

[0050] At that time, heat-exchange is carried out between the EGR gas flowing into the EGR passage 22 and a predetermined refrigerant in the EGR cooler 24 to cool the EGR gas.

[0051] The EGR gas which has flown back into the branching inlet pipe 8 from the branching exhaust pipe 18 through the EGR passage 22 is guided into the combustion chamber of each cylinder 2 while being mixed with the new air flowing from the upstream branching inlet pipe 8 and burns the fuel injected from the fuel injection valve 3 as an ignition source.

[0052] At this time, since inert gaseous components, such as water (H_2O) and carbon dioxide (CO_2), are contained in the EGR gas, when the EGR gas is included in the gaseous mixture, combustion temperature of the gaseous mixture is lowered, thereby allowing control over the amount of generated nitrogen oxide (NO_x).

[0053] Further, when the EGR gas is cooled in the EGR cooler 24, since the temperature of EGR gas itself decreases while the volume of the EGR gas is reduced, the ambient temperature in the combustion chamber does not rise needlessly when the EGR gas is supplied into the combustion chamber, and also, the amount of new air (volume of new air) supplied into the combustion chamber is not reduced needlessly.

[0054] Further, a fuel addition mechanism is disposed to the internal combustion engine 1 for adding fuel in the exhaust air. This fuel addition mechanism comprises a fuel addition valve 25 which opens when driving power is impressed so as to allow fuel injection from the inside of the exhaust port of the No. 1 (#1) cylinder 2 toward the inside of the branching exhaust air pipe 18 and a fuel supply passage 26 for supplying a part of the fuel supplied from the fuel pump 6 to the above-mentioned fuel addition valve 25.

[0055] In the reducing agent feeding mechanism constituted in this manner, a part of the fuel supplied from the fuel pump 6 is fed to the fuel addition valve 25 through the fuel supply passage 26. The fuel addition valve 25 opens with the impressed drive power and injects fuel towards the inside of the branching exhaust air pipe 18.

[0056] The fuel injected into the branching exhaust air pipe 18 from the fuel addition valve 25 flows into the pre-catalyst 21 through the turbine housing 15b and the exhaust pipe 19 along with the exhaust air flowing from the upstream branching exhaust air pipes 18 and subsequently flows into the particulate filter 20 from the pre-catalyst 21.

[0057] At this time, if nitrogen oxide (NO_x) has been occluded in the NO_x occlusion agent of the particulate filter 20, that nitrogen oxide (NO_x) is reduced and purified using the above-mentioned fuel in the gas as a reducing agent.

[0058] Further, since platinum (Pt), an oxidation catalyst, is supported by the particulate filter 20, oxygen and fuel included in the above-mentioned gas cause an oxidation reaction with the oxidation catalyst to raise the temperature in the particulate filter 20. Since production of active oxygen by the NO_x occlusion agent accelerates when the temperature in the particulate filter 20 rises as described above, the PM trapped by the particulate filter 20 can also be oxidized and cleaned.

[0059] Further, since the NO_x occlusion agent supported by the particulate filter 20 occludes sulfur oxide (SO_x) in the exhaust air through the same mechanism applied to the nitrogen oxide (NO_x), when the temperature in the particulate filter 20 rises with the added fuel as described above while the oxygen concentration in the particulate filter 20 comes to be under stoichiometric atmosphere or rich atmosphere, the sulfur oxide (SO_x) being absorbed in the NO_x occlusion agent is heat-decomposed to form SO_3- or SO_4-, and thereafter SO_3- or SO_4- reacts with hydrocarbon (HC) and carbon monoxide (CO) in the exhaust air and is reduced to gaseous SO_2-.

[0060] An electronic control unit (ECU: Electronic Control Unit) 27 for controlling this internal combustion engine 1 is installed parallel to the internal combustion engine 1 configured as described above.

[0061] In addition to the above-mentioned common-rail pressure sensor 4a, air flow meter 11, intake air temperature sensor 12, and

intake air pipe pressure sensor 17, this ECU 27 is also connected to various other sensors, such as crank position sensor 28 attached to the internal combustion engine 1, water temperature sensor 29, accelerator opening sensor 30 which outputs an electric signal corresponding to the operation amount of an accelerator pedal (not shown in the figure), etc. via electric wiring, so that signals outputted from these various sensors are inputted to the ECU 27.

[0062] In addition to the above-mentioned various sensors, the fuel injection valve 3, actuator 14 for throttling the intake air, EGR valve 23, fuel addition valve 25, etc. are connected to the ECU 35 via electric wiring, allowing the ECU 35 to control the fuel injection valve 3, actuator 14 for throttling the intake air, EGR valve 23, fuel addition valve 25, etc. corresponding to the signals outputted from the above-mentioned various sensors.

[0063] Next, the following will describe the concrete configuration of the pre-catalyst 21 in this embodiment.

[0064] The pre-catalyst 21, as shown in FIG. 2, is equipped with a carrier substrate 210 having a plurality of exhaust air flow passages which are so arranged as to form a shape similar to honeycomb. This carrier substrate 210 is made from, for example, a porous sintered metal such as cordierite.

[0065] The surface of the carrier substrate 210 is, as shown in FIG. 3, covered with a supporting layer 211, while an oxidation

catalyst 212 which is typically platinum (Pt) is supported by the supporting layer 211.

[0066] A coat layer consisting of alumina (Al_2O_3) is commonly used as the above-mentioned carrier layer. However, although it is hard to induce sintering of platinum (Pt) in the high temperature region, alumina (Al_2O_3) has a characteristic of easily occluding sulfur oxide (SO_x) in the exhaust air.

[0067] For this reason, the catalyst having a coat layer consisting of alumina (Al_2O_3) as a supporting layer causes unnecessary occlusion of sulfur oxide (SO_x) in the exhaust air to lower the cleaning capability of the catalyst, subsequently allowing SO_x poisoning to occur more easily.

[0068] When SO_x poisoning occurs to the catalyst, a process (hereafter called SO_x depoisoning process) of arranging the oxygen concentration in the exhaust air flowing into the catalyst into the concentration under oxygen-rich atmosphere (i.e., oxygen concentration of the exhaust air exhausted from the internal combustion engine operated under rich air-fuel combustion ratio) while the catalyst temperature is raised to 500°C to 700°C.

[0069] However, incidentally, by performing the above-mentioned SO_x depoisoning process, the sulfur oxide (SO_x) occluded in the catalyst is released to the exhaust air. This results in re-occlusion of sulfur oxide (SO_x) by the particulate filter 20 to create a problem

that the particulate filter 20 be subjected to SO_x poisoning at a needlessly accelerated speed.

[0070] Therefore, according to the exhaust emission control device of the internal combustion engine concerning this embodiment, a coat layer consisting of titania (TiO_2) or silica (SiO_2) which is hard to occlude sulfur oxide (SO_x) is used as the supporting layer 211 of the pre-catalyst 21.

[0071] Since the exhaust air discharged from the internal combustion engine 1 first flows into the pre-catalyst 21 if the pre-catalyst 21 configured as described above is disposed upstream from the above-mentioned particulate filter 20, the SOF in the exhaust air is oxidized and cleaned by the pre-catalyst 21.

[0072] By allowing the exhaust air to flow into the particulate filter 20 after SOF in the exhaust air is oxidized and cleaned by the pre-catalyst 21, SOF does not attach onto the upstream side end-face of the particulate filter 20.

[0073] As a result, since fine particles such as soot in the exhaust air are not absorbed and accumulated by the SOF on the upstream side end face of the particulate filter 20, plugging of the upstream side end face of the particulate filter 20 is prevented.

[0074] Further, since the support layer 211 of the pre-catalyst 21 comprises a coated layer consisting of titania (TiO_2) or silica (SiO_2) which does not easily occlude sulfur oxide (SO_x), sulfur oxide

(SO_x) in the exhaust air is hard to be occluded in the pre-catalyst 21, thus preventing the SO_x poisoning of the pre-catalyst 21.

[0075] When SO_x poisoning of the pre-catalyst 21 is prevented in this manner, the pre-catalyst 21 no longer requires the SO_x depoisoning process and, as a result, the particulate filter 20 is not subjected to accelerated SO_x poisoning attributed to the SO_x depoisoning process performed on the pre-catalyst 21.

[0076] However, since the NO_x occlusion agent of the particulate filter 20 occludes sulfur oxide (SO_x) according to the same mechanism for occluding nitrogen oxides (NO_x), the particulate filter 20 alone is subjected to SO_x poisoning.

[0077] For this reason, when SO_x poisoning of the particulate filter 20 occurs, it is necessary for the particulate filter 20 to receive SO_x depoisoning processing.

[0078] As a method of carrying out SO_x depoisoning processing on the particulate filter 20, for example, fuel is added to the exhaust air from the fuel addition valve 25. When fuel is added to the exhaust air from the fuel addition valve 25, a part of added fuel is oxidized (combusted) in the particulate filter 20 to raise the temperature inside the particulate filter 20 while the remaining added fuel acts as a reducing agent for sulfur oxide (SO_x).

[0079] In this case, since the pre-catalyst 21 also has an oxidation function, a fairly small quantity of fuel having been added to the exhaust air from the fuel addition valve 25 is oxidized by the

pre-catalyst 21. However, the heat generated by this process is consumed for vaporizing the above-mentioned added fuel, subsequently suppressing excessive elevation of the temperature of the pre-catalyst 21.

[0080] When exposed to high temperature, titania (TiO_2) and silica (SiO_2) forming the supporting layer 211 of the pre-catalyst 21 cause grain-growth and could induce sintering of the oxidation catalyst 212. However, even when SO_x depoisoning process is carried out to the particulate filter 20, since excessive temperature increase of the pre-catalyst 21 is prevented by adding fuel from the fuel addition valve 25 to the exhaust air upstream from the pre-catalyst 21, sintering of the oxidation catalyst 212 is prevented.

[0081] Further, when added fuel is vaporized and/or heat-decomposed by the pre-catalyst 21 as mentioned above to allow easy and homogeneous mixing of added fuel and exhaust air, the gas discharged from the pre-catalyst 21, in other words, the gas flowing into the particulate filter 20 consists of homogeneously mixed added fuel and exhaust air.

[0082] As a result, while the liquefied fuel is prevented from attaching or accumulating on the upstream side end-face of the particulate filter 20, added fuel can be uniformly spread in the wide area of the particulate filter 20.

[0083] Therefore, according to the exhaust emission control device of an internal combustion engine in this embodiment, since the

pre-catalyst 21 having the supporting layer 211 consisting of titania (TiO_2) or silica (SiO_2) is disposed upstream from the particulate filter 20, plugging at the upstream side end-face of the particulate filter 20 can be prevented while also preventing the excessive SO_x poisoning of the particulate filter 20.

[0084] As a result, with the exhaust emission control device of an internal combustion engine in this embodiment, the cleaning capacity of the particulate filter 20 can be utilized effectively, thereby allowing improvements over the emission of the internal combustion engine 1.

[0085] Although the present embodiment provided, as an example, the configuration that only the oxidation catalyst be supported by the supporting layer of the pre-catalyst, this invention is not limited to this configuration and may be so arranged as to support the NO_x occlusion agent and the like in addition to the oxidation catalyst. What matters for the configuration is that the supporting layer of the re-catalyst 21 has a characteristic of not easily occluding sulfur oxide (SO_x), and the catalyst supported by the supporting layer has a characteristic of oxidizing and cleaning SOF in the exhaust air.

[0086] Further, although the present embodiment described light oil which is the fuel for internal combustion engine 1 as an example of the reducing agent concerning this invention, the reducing agent is not limited to this substance as long as it generates a reducing

component, such as hydrocarbon, carbon monoxide, etc., in the exhaust air, wherein examples are gases, such as hydrocarbon, hydrogen, and carbon monoxide, liquids, such as propane, propylene, and butane, and liquid fuels, such as gasoline, kerosene, etc. However, in view of avoiding the cumbersome operations at the time of storing and supplying a reducing agent, light oil illustrated in the present embodiment is preferred.

[0087] Further, although the present embodiment explained based on an example configuring the pre-catalyst 21 and the particulate filter 20 in the exhaust pipe 19 of an internal combustion engine 1 to be housed in separate casings, the pre-catalyst and the particulate filter may be housed in the same casing.

[0088]

[Effect of the Invention] According to the exhaust emission control device of the internal combustion engine concerning this invention, since the pre-catalyst having an oxidation function is disposed upstream from the particulate filter in which the NO_x occlusion agent is supported, SOF never attaches on the upstream side end-face of the particulate filter.

[0089] Thereby, SOF in the exhaust air never get accumulated on the upstream side end-face of the particulate filter, subsequently suppressing the plugging at the upstream end-face of the particulate filter.

[0090] Further, according to the exhaust emission control device of the internal combustion engine concerning this invention, the pre-catalyst has a supporting layer consisting of titania (TiO_2) or silica (SiO_2) to prevent SO_x poisoning of the pre-catalyst.

[0091] As a result, SO_x depoisoning process is unnecessary for the pre-catalyst, subsequently preventing SO_x poisoning of the particulate filter attributed to the SO_x depoisoning process performed on the pre-catalyst.

[0092] Therefore, since the exhaust emission control device of the internal combustion engine concerning this invention can prevent the deterioration of cleaning capacity of the particulate filter, exhaust emission of the internal combustion engine is improved.

[Brief Description of the Drawings]

[FIG. 1] Diagram illustrating the outline configuration of an internal combustion engine and its suction-exhausting system to which this invention is applied.

[FIG. 2] Diagram illustrating the structure of the carrier substrate of the pre-catalyst.

[FIG. 3] Enlarged diagram illustrating the surface of the carrier substrate of the pre-catalyst.

[Explanation of the Reference Numerals]

1...Internal combustion engine

6...Fuel pump

18...Branching exhaust pipe

19...Exhaust pipe

20...Particulate filter

21...Pre-catalyst

25...Fuel addition valve

26...Fuel supply passage

210...Carrier substrate

211...Supporting layer

212...Oxidation catalyst

Figure 3
【図3】

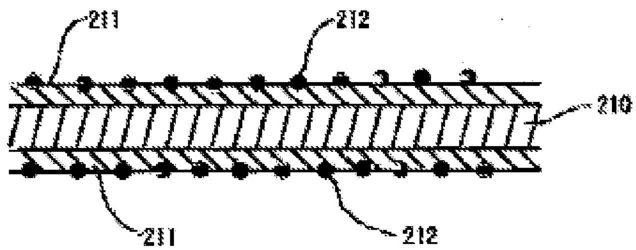

Figure 1
【図1】

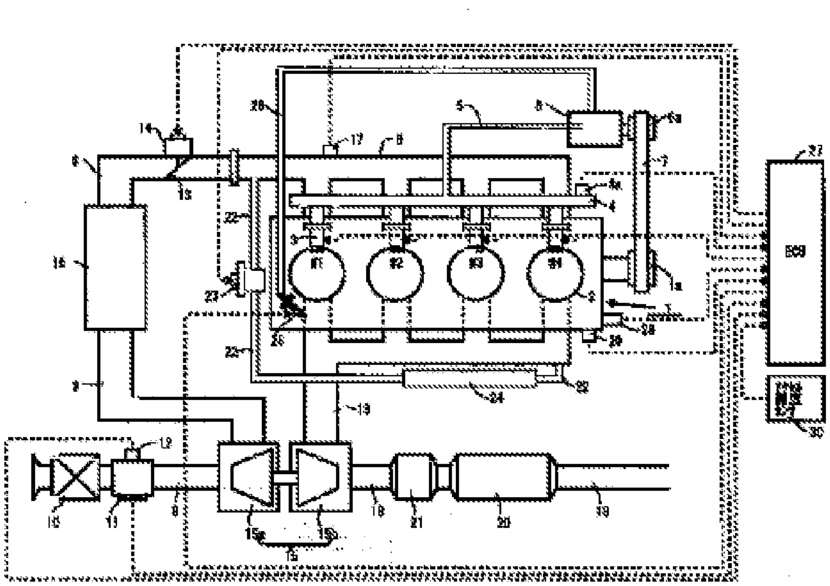

Figure 2
【図2】